TARTCHEK (Version 2002-1) Update

by
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Introduction

The primary documentation for TARTCHEK is still Chapter 7 of the TART95 documentation. This is merely a brief update on new and improved features of TARTCHEK.

Distributed with the on-line documentation are a number of color Postscript figures, that will be discussed below. These figures are in standard Postscript format that can be printed on any color Postscript printer or viewed with any Postscript viewer, such as Ghostview. In order to fully understand the following discussion I suggest that you view the figures using a Postscript viewer as you read the following text. If you do not have a Postscript viewer you can download one from the Web for FREE! **Starting with the 2000 distribution, these figures are also included directly in this document.**

Many TARTCHEK users are already aware of this code's ability to help you quickly verify input parameters for TART, particularly to verify geometry. **I STRONGLY RECOMMEND THAT YOU NEVER RUN TART WITHOUT FIRST USING TARTCHEK TO VERIFY YOUR INPUT.**

To verify TART input users have been using the Geometry page of TARTCHEK. What most users seem to still be unaware of is that TARTCHEK is designed to include many pages of options - Geometry is merely the first page of options that you see when the code starts. You can cycle through pages of options by using your mouse to click on the lowest option on each page. Here I'll briefly describe the next two pages of options.

Surfaces - the second page of options allows you to see your geometry in 3-D. Options allow you to make all low density zones invisible, shade objects, and slice them open so you can see inside of them. Best of all the new TARTCHEK ray tracing method runs about 200 times faster than the original method - that right - not 200 % faster - 200 times faster. Plots that used to take hours now take seconds. You will find that in just a few seconds or minutes you can rotate your geometry to look at it from many perspectives; by generating a series of plots you can walk around your geometry. In additional, as with any page of TARTCHEK options, you can obtain color Postscript output of anything that you see on your screen. The first two Postscript figures illustrates use of these features.

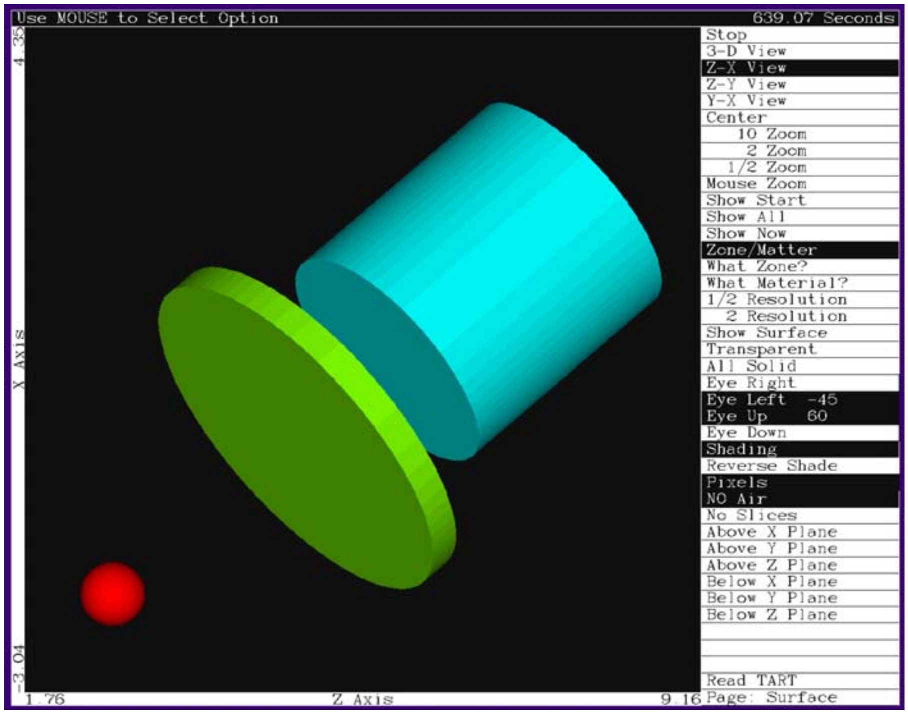

Fig. 1: 3-D View of COG Example Problem

The first figure **(COG.ps)** is a 3-D view of the geometry for the first example problem from the COG manual. We have a spherical photon source to the lower left (the red sphere). There is a lead filter in the middle (the green cylinder - here for convenience modeled as a cylinder; in the COG problem it is a rectangle). Finally there is a cylindrical detector to the upper right (the light blue cylinder). Later we will return to this problem when I discuss overlaying your results on your geometry.

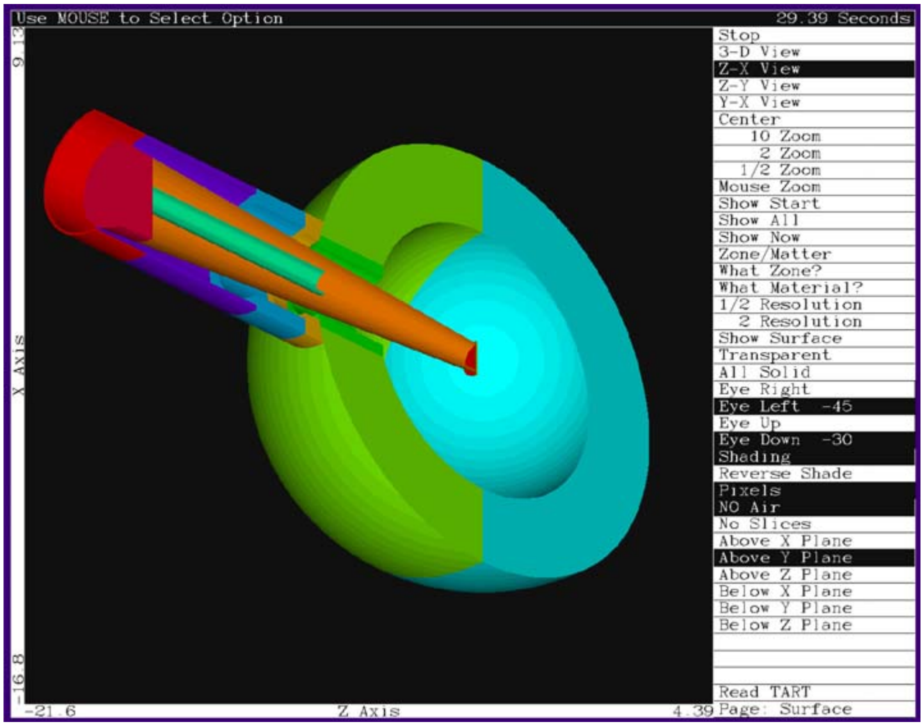

Fig. 2: Details on Pulsed Neutron Generator

The next figure **(PULSED.ps)** shows the details of the neutron generator and spherical shell used in a Livermore pulsed sphere measurements. In this case I have used the **SLICE** options to slice the geometry open, so that we can see inside of it. This is a very powerful option to let you examine your geometry in detail.

Flux Edit - The next page of options allows you to overlay the results of TART calculations directly onto your geometry; you can overlay energy deposition or flux to almost immediately see your results. To use this option, after you have run a TART source problem (neutron or photon source) you can run the utility code **FLUXEDIT** that will read your TART output file **TART.OUT** and prepare results for use by TARTCHEK in the file **FLUXEDIT.OUT**. When you then run TARTCHEK if you use the same TART input TART.IN and FLUXEDIT output file FLUXEDIT.OUT (put them both in your TARTCHEK directory) you can then immediately see what your results look like. Analysis that used to take weeks or months can now be done in a few minutes. The below third and fourth figures illustrate use of this feature.

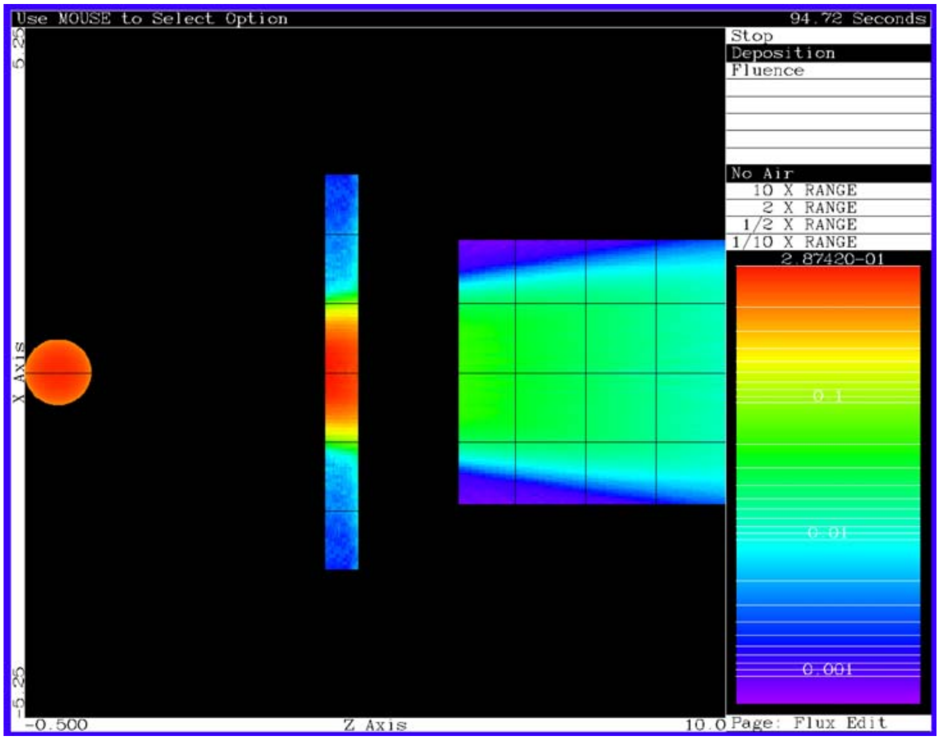

Fig. 3: Energy Deposit in COG Example

With the third figure **(DEPOSIT.ps)** we return of the first COG example problem, discussed above. For this example I have used a photon source directed at the detector and having a 20 degree angular spread. Here I illustrate energy deposition. With the absolute scale at the lower right of the figure we can read directly off the plot how the deposition is varying. Note the high deposition in the lead filter (as we would expect in a high Z material), and the lower deposition in the detector. We can also see the spatial variation of deposition in the detector. With figures similar to this it is really very easy to design experimental set-ups. For example, you can quickly check to see if this is really the thickness of lead filter you should use to achieve a given response in the detector. You can also check on other features that might not otherwise be obvious to you. For example, note the relatively high deposition on the side of the lead filter closest to the detector and outside of the photon source. This indicates a lot of backscatter from the detector, which might lead you to re-position the lead filter relative to the detector - something you might never have noticed when reading a long output listing - here you can see it minutes after you have run the TART calculation.

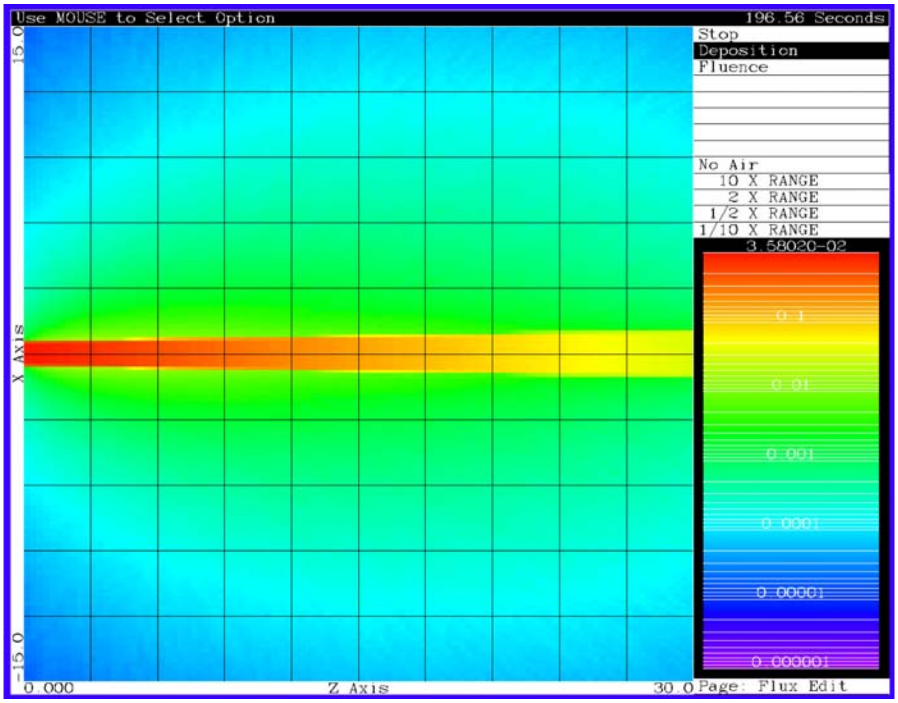

Fig. 4: 1 MeV Photon Incident on Water

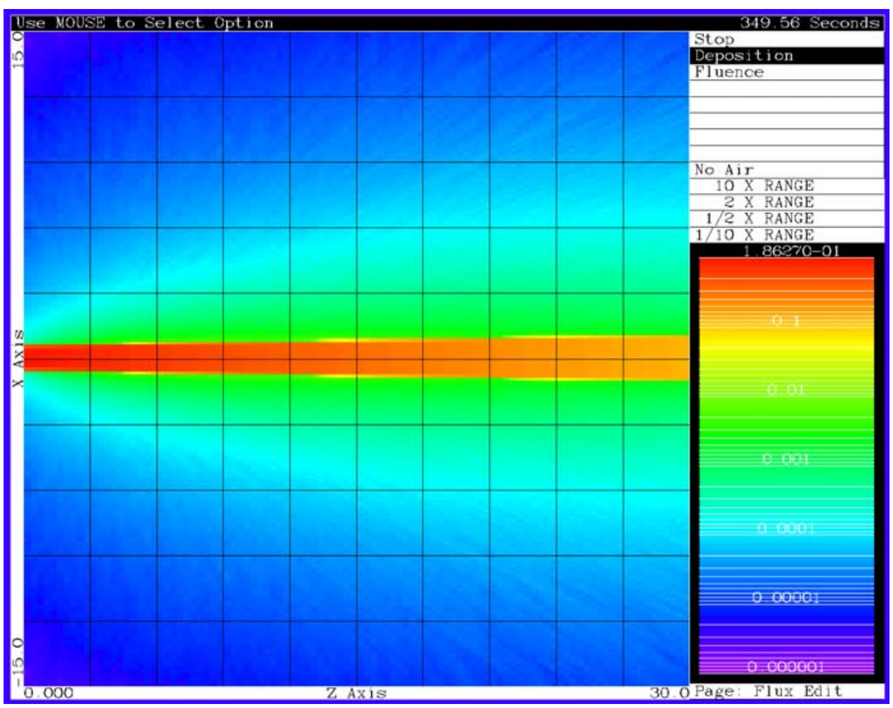

Fig. 5: 10 MeV Photon Incident on Water

The next two figures show the energy deposition in a water phantom due to 1 MeV **(PHANTOM1.ps)** and 10 MeV **(PHANTOM2.ps)** photons incident on the phantom from the left with a 1 degree angular spread. Here the geometry is modeled as a cylinder 30 cm high and 15 cm in radius. Recently a colleague asked me what I expected the difference to be in the energy deposition in a water phantom for a 1 MeV versus 10 MeV photon. Rather than try to explain I quickly used TARTAID to model his geometry using 100 by 100 zones in R by Z geometry; 10,000 zones. I then ran TART followed by FLUXEDIT, and minutes later we were looking at the results (as you can now do in the above two figures). By comparing results for 1 and 10 MeV photons the difference in the results were immediately obvious. Finally to understand why the results are different we used **EPICSHOW** to look at the oxygen photon cross sections; see the **EPICSHOW** on-line documentation. Using EPICSHOW to display the oxygen photon cross sections we could see that the total cross section at 1 MeV is considerably larger than at 10 MeV, so we expect more of the photons to collide and deposit their energy at 1 MeV, compared to 10 MeV. That's part of the picture; the rest is that the lower energy photons will scatter through larger angles and spread out more from the incident photon beam. The whole process, TARTAID, TART, TARTCHEK and EPICSHOW took only about 20 minutes = problem solved – and most important = results understood!

The bottom line is that by using the TART system codes in combination you can do more than just generate numbers; you can quickly improve your understanding of exactly what's happening in your problems, and more importantly you can improve your understanding of WHY it is happening. When I say quickly I mean QUICKLY! When you use this code system you will be amazed at how quickly you can accomplish results.

Recent Addition - Comparing Photons and Neutrons

The above comparison of 1 and 10 MeV photons incident on water has become very popular with readers, and they have asked for additional examples. For example, several readers have asked for results of 1 or 10 MeV neutrons incident on water. The next two figures show the energy deposition in a water phantom due to 1 MeV **(PHANTOM3.ps)** and 10 MeV **(PHANTOM4.ps)** neutrons incident on the phantom from the left with a 1 degree angular spread (exactly the same situation as in the case of the above photons).

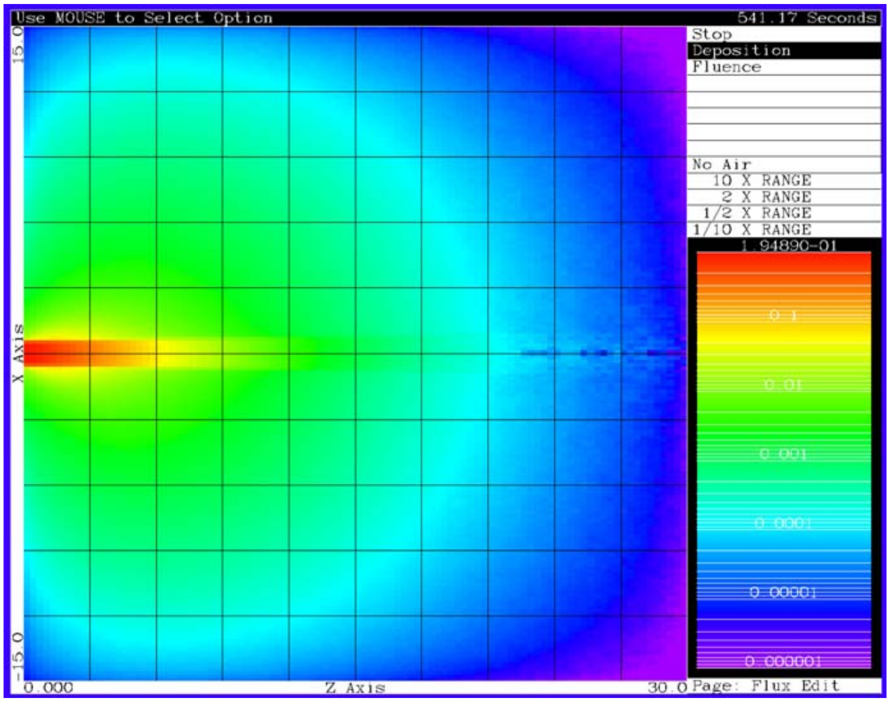

Fig. 6: 1 MeV Neutrons Incident on Water

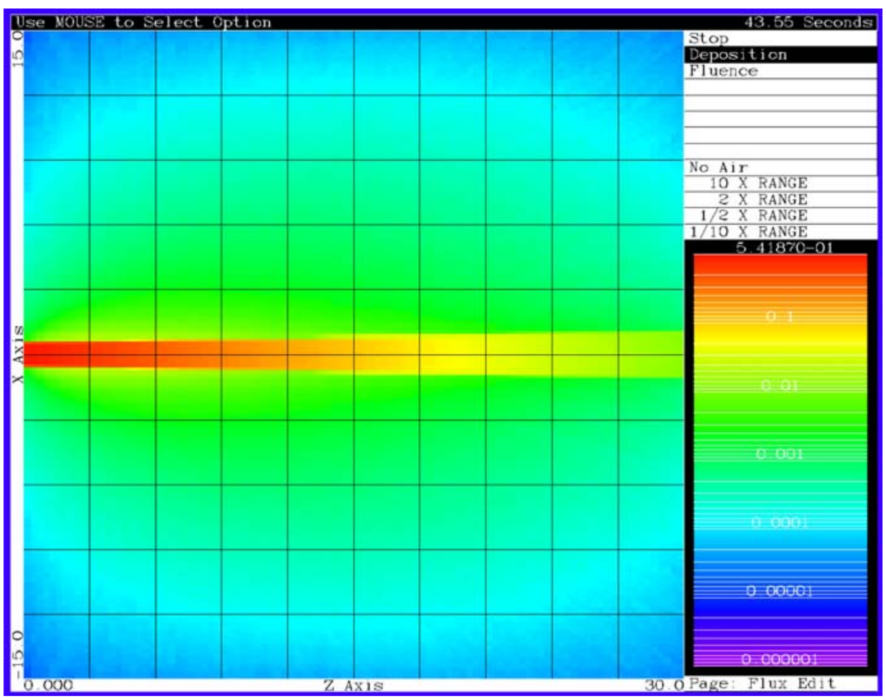

Fig. 7: 10 MeV Neutrons Incident on Water

From the TART output report we can see that for water at a density of 1 gram/cc the mean free path for photons is, 1 MeV: 14.15 cm, 10 MeV: 46.1 cm, and for neutrons it is, 1 MeV: 2.1 cm, 10 MeV: 9.4 cm. From the TART output report we can also determine that the expected energy loss per cm for photons is, 1 MeV: 0.031 MeV/cm, 10MeV:

0.17 MeV/cm, and for neutrons it is, 1 MeV: 0.176 MeV/cm, 10 MeV: 0.36 MeV/cm.

By comparing the photon and neutron results we can see that of the two the neutron cross sections are much higher, so that fewer neutrons are transmitted through the 30 cm thickness of water, e.g., with a mean free path of only 2.1 cm there is only a very small probability that any 1 MeV neutrons will be transmitted through the water. In addition the energy deposition (MeV/cm) is higher in the case of neutrons, so not only do the neutrons have more collisions per cm, they also lose more energy per cm of travel. We can see from the photon results that generally photons scatter through relatively small angles, so they more or less go where you point them. In contrast we can see from the neutron results that neutrons scatter through larger angles and can be very invasive, spreading their energy deposition over a relatively large area.

Recent Addition - Comparing Low and High atomic Number Materials

All of the above results are for water, here defined as simply two atoms of hydrogen for each atom of oxygen (H2O), normalized to an overall density of 1 gram/cc. Therefore in this case we have seen results for low atomic number materials: hydrogen, Z = 1, and oxygen, Z = 8. You can learn a lot by doing the same calculations for a high atomic number material, and comparing the results.

The following results using exactly the same geometry that we used in the above examples, namely a cylinder 15 cm in radius and 30 cm thick, and the same source distributions, namely, 1 or 10 MeV, photons or neutrons, with a one degree angular spread. The only difference will be that in this case we will use lead (Pb) at 11.35 grams/cc, instead of water at 1 gram/cc; this will show us results for a high atomic number material, Z = 82, that we can compare to the water results.

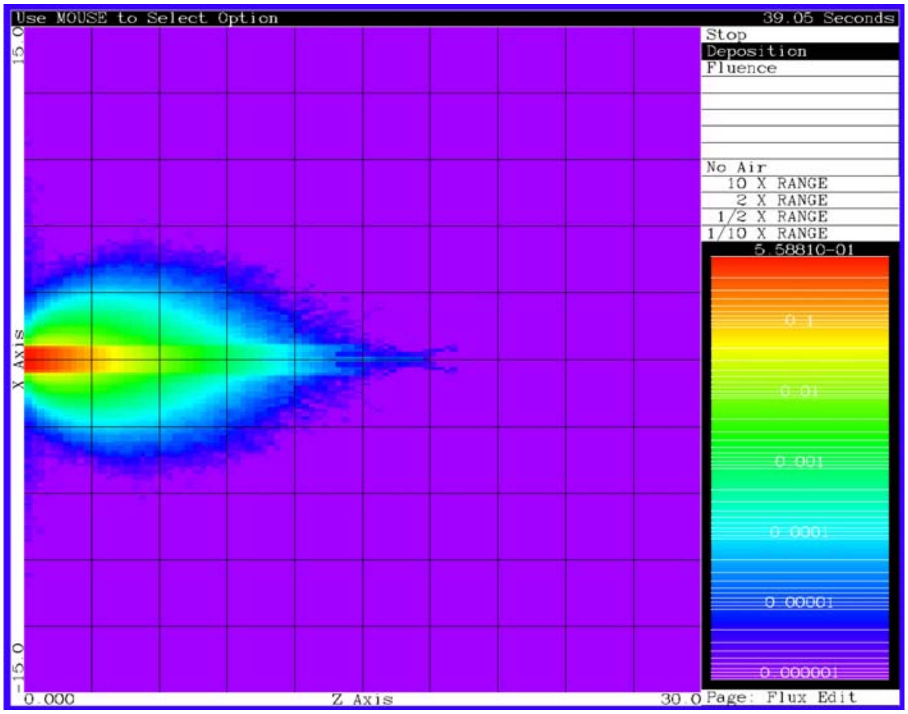

Fig. 8: 1 MeV Photon Incident on Lead

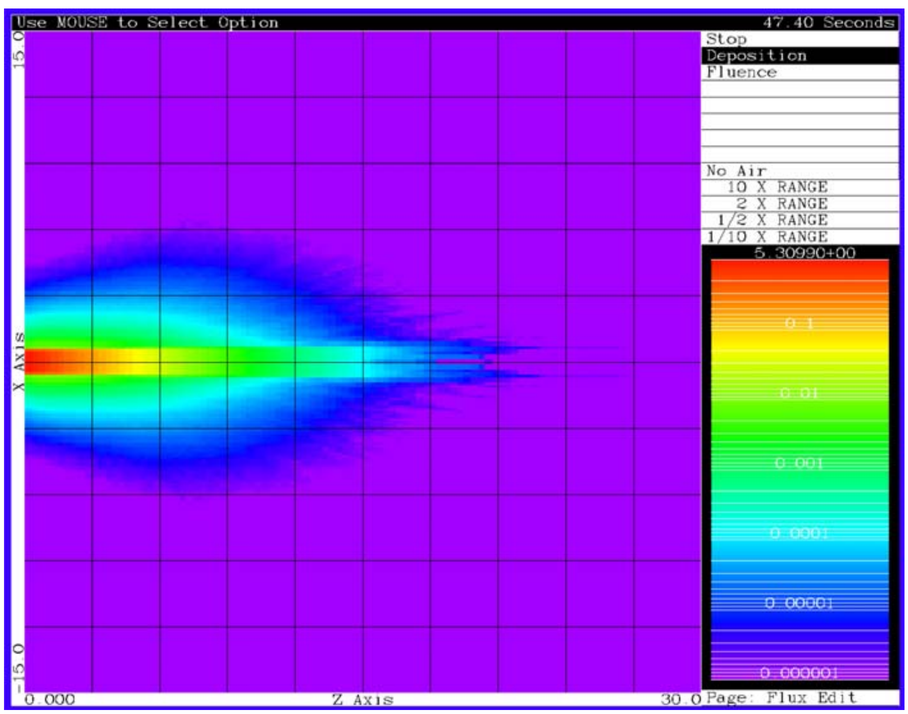

Fig. 9: 10 MeV Photon Incident on Lead

The next two figures are for 1 **(PHANTOM5.ps)** and 10 **(PHANTOM6.ps)** MeV **photons** incident on lead. For a 1 MeV photon the mean free path is only 1.25 cm, and the expected energy loss is 0.44 MeV/cm, and for a 10 MeV photon the mean free path is

1.75 cm, and the expected energy loss is 5.1 MeV/cm. We can see from the figures that in this case the mean free paths are so small that virtually nothing gets through the 30 cm thickness of lead; everything is deposited in a fairly narrow volume about the original direction of the source. By comparing the water and lead results we can see that the photons cross sections increase rapidly with the atomic number (Z) of the target, so that high atomic number materials are very effective at stopping photons.

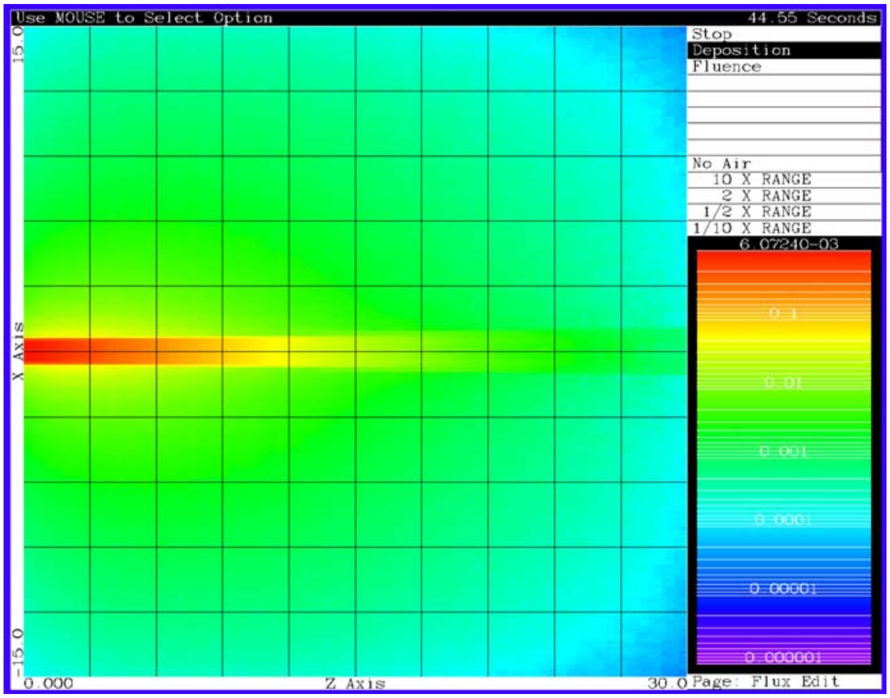

Fig. 10: 1 MeV Neutron Incident on Lead

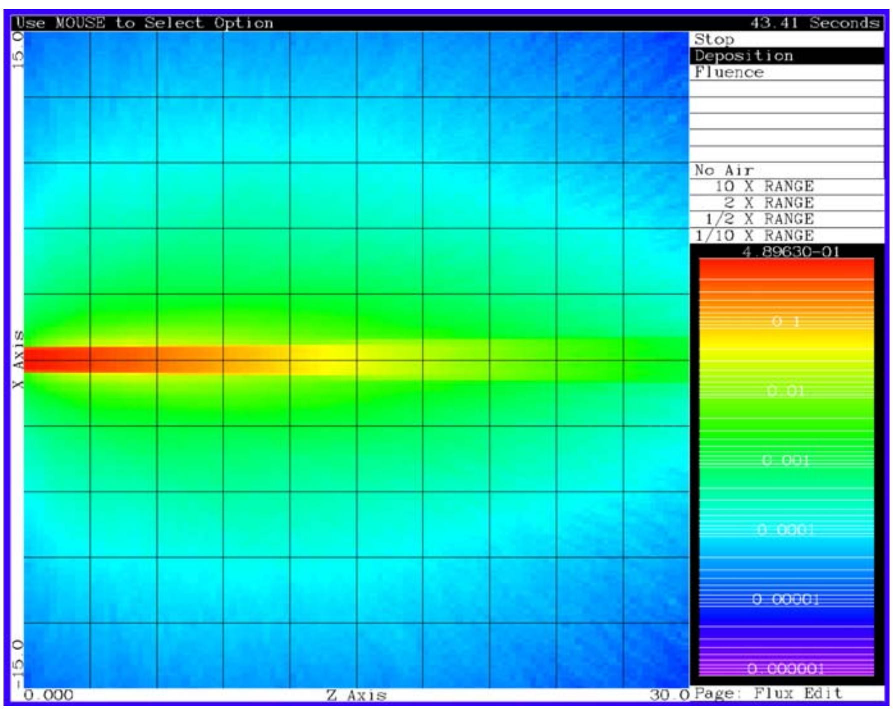

Fig. 11: 10 MeV Neutron Incident on Lead

The next two figures are for 1 **(PHANTOM7.ps)** and 10 **(PHANTOM8.ps)** MeV **neutrons** incident on lead. For a 1 MeV neutron the mean free path is about 5 cm, and the expected energy loss is only about 0.006 MeV/cm, and for a 10 MeV neutron the mean free path is also about 5 cm, and the expected energy loss is about 0.45 MeV/cm.

By comparing the water and lead results we can see that they are fairly similar, indeed for 1 MeV neutrons it is easier for them to penetrate the lead than the water. This might seem surprising to you since for a thickness of 30 cm, we are comparing 30 grams of water to 340.5 grams of lead. But what these results illustrate is that the low atomic weight materials in water, particularly the hydrogen (Z=1) is very effective at moderating neutrons and reducing their energy to a sufficiently low value that they can be absorbed by the hydrogen. In contrast the high atomic weight of lead means that it is not a very good neutron moderator, so that neutrons will scatter around in the lead and spread out a lot before they are finally absorbed.

To further improve your understanding of the lead results you can also use EPICSHOW to see the lead photon cross sections (**PbPxc.ps**) and expected photon energy deposition (**PbPdep.ps**) as well as the lead neutron cross sections (**PbNxc.ps**) and neutron expected energy deposition (**PbNdep.ps**). Note, for example, the relatively small lead neutron absorption cross section, which allows neutrons to transport very well through lead. Only after neutrons have scattered to lower energies can they be effectively absorbed.

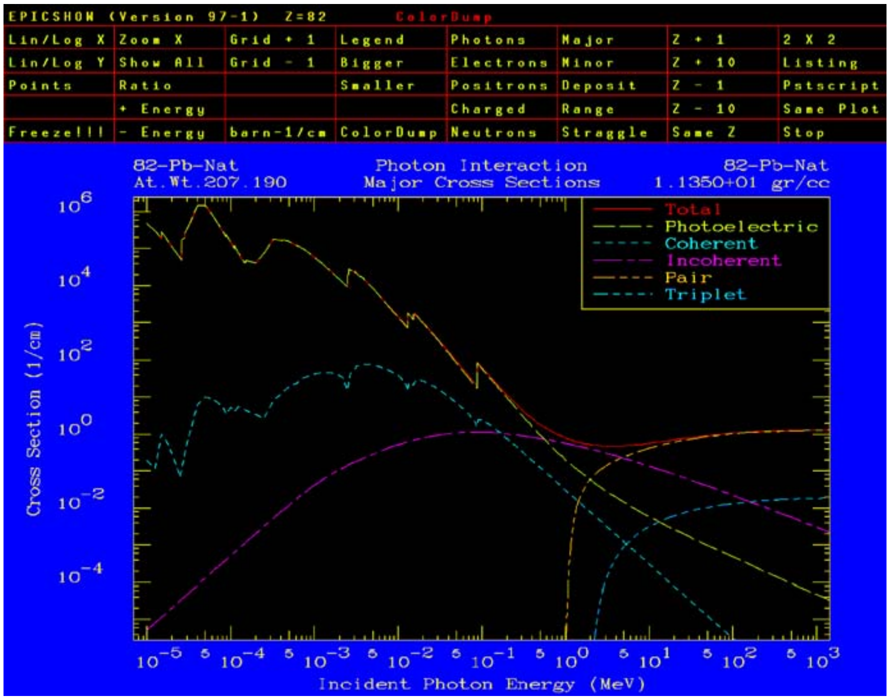

Fig. 12: Lead Photon Cross Sections

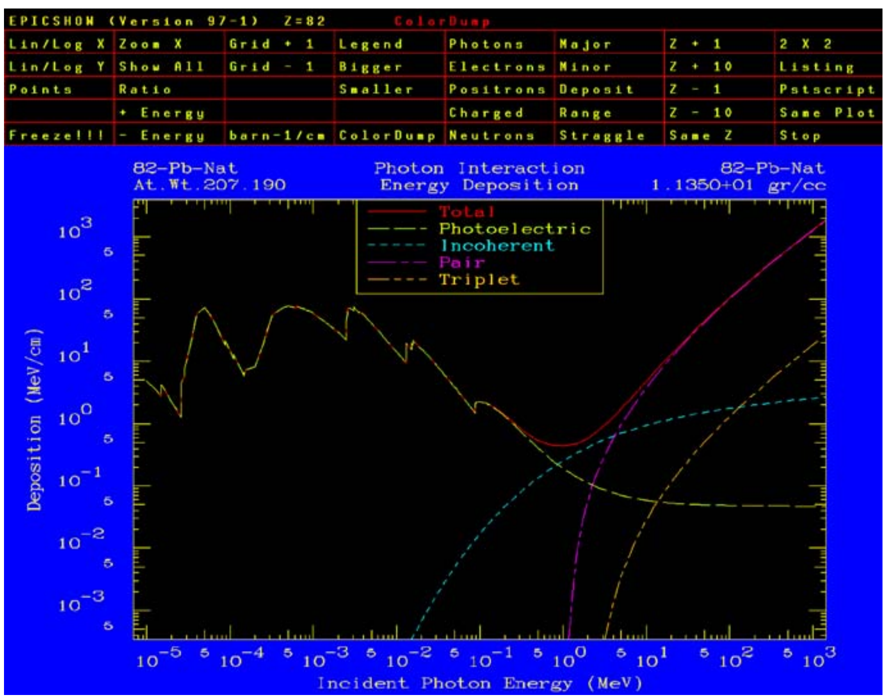

Fig. 13: Lead Photon Expected Energy Deposit

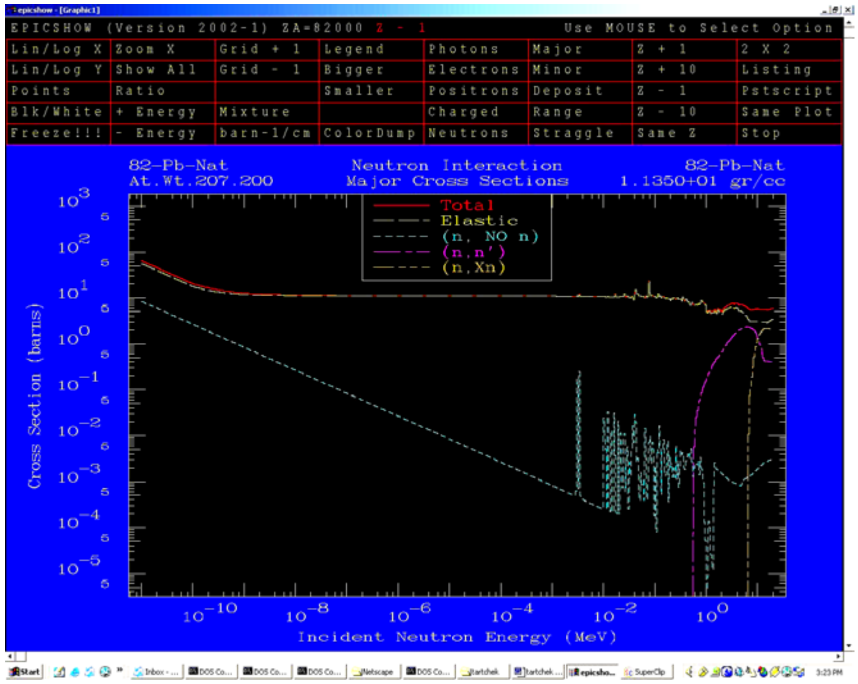

Fig. 14: Lead Neutron Cross Sections

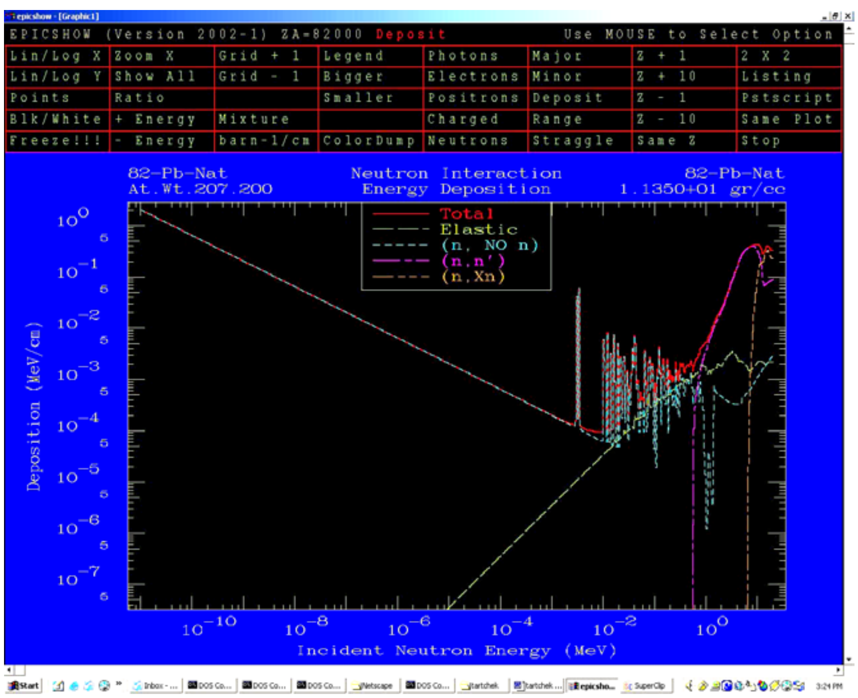

Fig. 15: Lead Neutron Expected Energy Deposit